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INFLUENCE ON LINSEED OIL OF THE GEOGRAPHICAL SOURCE AND VARIETY OF FLAX.[1]

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INTRODUCTION.

The cultivation of flax for the production of flaxseed and for linseed oil is at present receiving the most careful attention of agriculturists as well as manufacturers. The interest in this important problem is twofold. The matter resolves itself into a problem of rehabilitation of the crop on the one hand, due to a diminishing acreage and yield of seed, while on the other hand interest is stimulated by the constantly increasing demand for the manufactured products with the growing scarcity of the linseed oil used in their manufacture. Practically the whole output of linseed oil is consumed in the manufacture of paints and varnishes and other allied materials where protective coatings are desired.

In view of these conditions, it is important that attention be directed at the present time to the improvement of the crop and the oil. The desired results can best be accomplished by a combined agronomic and chemical investigation of the subject. The investigation should embody a study of the culture of the plant for the production of seed, supplemented by a thorough study of the oil from the standpoint of yield and quality.

[1] The work discussed in this paper was carried out in cooperation with the Office of Cereal Investigations of the Bureau of Plant Industry. The writer wishes to express his thanks to Mr. C. H. Clark, assistant agronomist, in charge of flax investigations in that office, who supplied the samples, and to Mr. J. D. McIntyre, of the Office of Drug-Plant and Poisonous-Plant Investigations, who rendered assistance in the extraction of the oils.

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The growth of the plant, as well as the yield and quality of the oil, will be influenced to a certain degree by geographical location with the varying conditions of soil and climate. Therefore the cultivation of the plant in various geographical locations followed by analysis of the oil, both as regards yield and quality, serves as an excellent combination for comparison with respect to the effect of plant selection and geographical source upon the oil. A study of this problem was accordingly undertaken along the lines mentioned.

During two successive seasons selected varieties of flax were grown in widely separated localities having different soil and climatic conditions. The oil was extracted from the seeds of different varieties thus obtained and the various oils compared each year in order to ascertain any existing differences in composition in the different varieties when grown in one or several localities. The varieties upon which these studies were made represented two or more distinct types of flax. The quality of these oils from the standpoint of their usefulness as paint and varnish oils was studied and this information made available for use in the selection of varieties combining yield and quality of oil in any one or all localities.

VARIETIES OF FLAX.

Four varieties of flax were chosen and used as a basis for the investigation. These were selected by the Office of Cereal Investigations as representing two distinct types of seed flax. Reference will be made to the varieties as C. I. (Cereal Investigations) numbers.

The four varieties grown and tested for oil content and composition are as follows: C. I. No. 3, Damont (North Dakota 1215); C. I. No. 12, Primost (Minnesota No. 25); C. I. No. 13 (North Dakota Resistant No. 114); C. I. No. 19 (Russian). C. I. Nos. 3 and 19 represent typical seed-flax varieties, while C. I. Nos. 12 and 13 are earlier maturing and resistant varieties yielding less under semiarid conditions.

These varieties were grown during the seasons of 1914 and 1915 at stations located as follows: Moccasin, Mont.; Dickinson and Mandan, N. Dak.; Newell and Highmore, S. Dak.; Archer, Wyo., and Burns, Oreg. These stations are located in more or less widely separated flax-growing localities where the conditions of soil and climate are likewise different.

The conditions at the various stations with respect to altitude, soil, precipitation, and evaporation are shown in Table I.

Considerable variation in latitude and longitude exists between the several stations. The variation in longitude is 19° 40′ and in latitude 5° 18′. The northernmost stations are Moccasin, Mont., and Dickinson, N. Dak.; the southernmost is Archer, Wyo. Highmore, S. Dak., is located farthest east, while Burns, Oreg., is the most westerly station.

TABLE I.—*Location, soil, and climatic conditions of the seven stations where flax experiments were made during the seasons of 1914 and 1915.*

[Data from the records of the Biophysical Laboratory of the Bureau of Plant Industry.]

Station.	Latitude N.		Longitude W.		Altitude in feet.	Soil.	Year.	Precipitation for 5 months, April to August.	Evaporation for 5 months, April to August.
	°	′	°	′				*Inches.*	*Inches.*
Moccasin, Mont	47	00	109	45	4,300	Dark clay loam; gravel subsoil.	1914	10.03	27.173
							1915	11.98	25.059
Dickinson, N. Dak	47	00	103	00	2,453	Sandy to heavy clay loam	1914	18.84	26.975
							1915	14.77	21.06
Mandan, N. Dak	47	00	101	00	1,750	Sandy loam	1914	19.04	28.894
							1915	19.52	24.969
Newell, S. Dak	44	35	103	26	2,950	Pierre clay gumbo	1914	7.86	30.917
							1915	15.82	22.501
Highmore, S. Dak	44	30	99	20	1,890	do	1914	13.06	....
							1915	17.18	....
Archer, Wyo	41	42	104	15	6,027	Sandy loam; some gravel	1914	8.56	....
							1915	12.69	25.356
Burns, Oreg	43	00	119	00	4,100	Variable silt loam	1914	4.27	35.456
							1915	2.90	34.893

The soil at the different stations varies from a silt loam at Burns, to a clay gumbo at Highmore and Newell. The remaining stations possess sandy or clay-loam soils. The total precipitation during the growing months at the different stations varied considerably during the two seasons. The evaporation shows wide differences also.

The variation in location, soil, and climate doubtless affected the growth and development of the flax plants and therefore also affected the formation and development of the fatty oil in the seeds.

FACTORS WHICH INFLUENCE THE COMPOSITION OF THE OIL.

Conditions of soil and climate are important factors influencing the growth of a plant, and they act jointly in affecting the content and composition of the fatty oil in the plant. The availability of the fertilizer ingredients of soils is due to a large extent to the amount of moisture present, which in turn is dependent upon certain other conditions, such as heat, light, humidity, and altitude. Whether the soil is light or heavy in texture is important in making its constituents available to the plant. Likewise, the retention of moisture by some soils and the lack of retention by others naturally affect the growth and development of the plant and the formation of oil in the plant. Any cause which tends to modify the growth or nutrition of a plant will have a material effect upon the formation of the fat in the seed of the plant. Woods [1] states that the texture and structure of the soil affects decidedly the availability to the

[1] Woods, A. F. The relation of nutrition to the health of plants. *In* Yearbook, U. S. Dept. of Agr., for 1901, p. 157.

plant of the soil foods with air and water. Garner, Allard, and Foubert [1] have shown that climatic conditions exert a marked influence upon the oil content of certain seeds. Provided the content of oil is affected by environmental conditions it is very probable that the composition or the proportion of the component parts of the oils is likewise modified and altered.

Pigulevskii [2] has found from an examination of numerous plants in respect to oil content and composition that the nature of the oil in a plant is influenced by climatic conditions and possibly also by conditions of nutrition. A large number of plants of the same family grown in different parts of Russia yielded oils the nature of which varied with climatic conditions.

The effect of such climatic conditions as latitude, temperature, sunshine, and rainfall have been studied by Wiley [3] and found to influence the sugar content of sugar beets strongly. Likewise, the starch and protein content of the wheat grain have been found to be influenced by season and climate.

Various localities will be found to have varying conditions of climate and soil, the extremes and means of which act in either facilitating or retarding the growth of the plants and therefore affect favorably or unfavorably the formation of oil in the seeds.

PLAN OF COMPARISON OF THE OILS.

The present investigation was undertaken in order to compare the oils from the various flax samples grown at the several stations during the two successive seasons. The comparison in question should determine tentatively those varieties producing seeds with the highest yield of oil as well as oil of the best quality. Information of such character is of the utmost importance in connection with the production and improvement of this staple crop. However, it is not only important to ascertain the high oil-yielding varieties of seeds, but the properties and general behavior of the oils are of equal importance. The physical and chemical properties of the oils determine their value to a large extent. In order to facilitate the best comparison, only those properties which admit of accurate measurement and which have a direct bearing upon the quality of the oils were considered.

Color, specific gravity, and index of refraction are important physical properties in which variations can easily be detected. Since the color of most drying oils is an important consideration, but does not admit of measurement, it was necessary to describe

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[1] Garner, W. W., Allard, H. A., and Foubert, C. L. Oil content of seeds as affected by the nutrition of the plant. *In* Journ. of Agr. Res., U. S. Dept. Agr., v. 3, p. 248. 1914.

[2] Pigulevskii, C. V. *In* Zhurn. Russk. Fiz.-Khim. Obshch., v. 47, p. 393–405, 1915; v. 48, p. 324–341, 1916.

[3] Wiley, H. W. Influence of environment on composition of plants. In Yearbook, Dept. of Agr., for 1901, p. 307, 310.

this property as carefully as possible. The specific gravity and the refractive index, which have much significance as regards the general composition of the oils, were readily determined.

The chemical properties are perhaps most important from the standpoint of the composition of the oils. The acid, saponification, and iodin values are the most important chemical constants. The acid value of the linseed oils is affected by a number of conditions. Factors such as rain or moisture during harvest and the storing of the moist flax after harvest, which would tend to produce molding of the seed, will modify considerably the acid value of the oil. The saponification value representing the sum of the acid and ester values is a combined measure of the free acids and glyceryl esters contained in the oil.

Linseed oil consists for the most part of glyceryl esters of linoleic and linolic acids. These unsaturated fatty acids possess the property of absorbing iodin. This property is known as the iodin value and is perhaps the most important of the chemical constants. The iodin value is a direct criterion of the proportion of these fatty acids present in the oil, and since these acids determine the drying property of linseed oil the iodin value becomes an index of this property.

The usefulness of linseed oil in the industries is based upon the property of the oil to dry to a tough elastic film when exposed in thin layers to the air. This oil is a typical example of a class of fatty oils known as drying oils. Oils of this character are composed largely of glycerids of unsaturated fatty acids which possess the property of absorbing oxygen when exposed to the air. The absorption of oxygen by linseed oil alters its composition and is accompanied by the formation of a compound known as linoxyn, which constitutes the tough elastic skin so familiar when the oil is allowed to dry. The usefulness of linseed oil as a protective coating is due entirely to the formation of the compound linoxyn, which is resistant to the effects of heat and moisture of the outside elements to a remarkable degree.

Coincident with the absorption of oxygen there occurs an increase in the weight of the oil, and the more rapid the increase in weight the greater is the rapidity of drying, and vice versa. Advantage was taken of this property in order to determine the relative drying value of the various oils under consideration.

YIELD AND PHYSICAL PROPERTIES OF THE OILS.

Two methods were used for the extraction of the flax samples, namely, ether extraction and cold expression. The former method was applied to determine the actual yield of oil in the seeds, while the method of cold expression was employed to obtain working samples of the various oils for the determination of the physical and

chemical constants. Ether extractions were made by means of the customary Soxhlet extractors, while a small laboratory hydraulic press served for the cold expression of the oil. The yields of oil given in all cases represent ether-extracted oils, whereas all physical and chemical properties were determined upon cold-pressed oils.

It must be borne in mind that these cold-pressed samples differ from ordinary commercial raw linseed oils, being obtained under entirely different conditions. The results obtained are therefore comparable with each other, but not with commercial linseed oils.

The color was carefully noted in each case. Considerable diversity appeared and the colors are described as well as possible in order to bring out the existing differences.

The specific gravity and the refractive index, being affected by the composition of the oils, were carefully determined. Both of these constants bear a certain relationship to the composition of the oil.

Table II was prepared to show the similarities and differences in yield and physical properties of the various oils examined. The yield of oil and physical properties are arranged according to the stations at which the several varieties of flax were grown. Each Cereal Investigations number of flax grown at any station is given, together with the yield of oil during the two years. This arrangement permits a comparison of the varieties grown at each station during the two successive seasons.

By a careful study of Table II it will be seen that the samples of flax bearing Cereal Investigations numbers grown at each station during either of the two years vary considerably in yield of oil. This variation is apparent at each of the stations. Since each of the numbers represents a different variety, the differences in the yield of oil may be attributed to the varieties. When the same variety as grown at widely separated stations shows differences in yield of oil, it is probable that climatic and soil conditions play an important part.

In comparing the Cereal Investigations numbers of any one station during the two years, the yields of oil in many cases are distinctly comparable. While not constant, a certain degree of constancy is noticeable among them.

In order to make a better comparison of the Cereal Investigations numbers, not only at each station but at all the stations, the average oil yields were calculated and are included in Table II. A glance at the average yield of oil from the various Cereal Investigations numbers discloses those producing the highest and lowest yields at each station. It is noticed that Nos. 3 and 19 occupy a high position with regard to oil content, while Nos. 12 and 13 are usually low. The stations producing the highest and lowest oil yields are also clearly indicated in Table II.

TABLE II.—*Yield and physical properties of various oils from the flax crops of 1914 and 1915.*

[Color abbreviations: B=brown, d=deep, g=golden, l=lemon, p=pale, r=reddish, v=very, y=yellow.]

Station and C. I. No. of seed sample.	Yield of oil (per cent).			Color.		Specific gravity at 24° C.			Index of refraction at 24° C.	
	1914	1915	Average.	1914	1915	1914	1915	Average.	1914	1915
Moccasin, Mont.:										
No. 3	34.8	34.12	34.46	gy	pgy	0.9273	0.9283	0.9278	1.4770	1.4776
No. 12	32.5	33.00	32.70	ly	pgy	.9293	.9288	.9290	1.4776	1.4778
No. 13	33.0	34.50	33.75	gy	dly	.9268	.9305	.9286	1.4772	1.4784
No. 19	37.1	......	37.10	gy	pgy	.9262	.9286	.9274	1.4782	1.4770
Seasonal average	34.35	33.87	......	......	......	.9274	.9290			
Dickinson, N. Dak.:										
No. 3	36.8	37.03	36.91	pgy	vdgy	.9308	.9291	.9299	1.4808	1.4785
No. 12	34.6	33.00	33.80	dly	pgy	.9315	.9293	.9304	1.4806	1.4782
No. 13	31.4	32.20	31.80	vdly	vdgy	.9305	.9295	.9300	1.4802	1.4789
No. 19	35.3	37.10	36.20	dly	pb, r. tint.	.9302	.9289	.9290	1.4801	1.4782
Seasonal average	34.52	34.82	......	......	......	.9307	.9292			
Mandan, N. Dak.:										
No. 3	34.0	33.80	33.9	pgy	vpg	.9280	.9298	.9289	1.4781	1.4790
No. 12	31.44	35.70	33.57	ply	vpgy	.9278	.9292	.9285	1.4790	1.4788
No. 13	33.24	34.72	33.98	dly	gy	.9285	.9300	.9292	1.4795	1.4790
No. 19	35.6	35.50	35.55	dly	pgy	.9274	.9301	.9287	1.4783	1.4787
Seasonal average	33.74	34.93	......	......	......	.9279	.9298			
Newell, S. Dak.:										
No. 3	35.70	37.40	36.55	dgy	pgy	.9269	.9295	.9282	1.4765	1.4787
No. 12	30.30	37.20	33.75	dgy	vpgy	.9261	.9292	.9276	1.4760	1.4783
No. 13	32.10	31.80	31.45	pgy	vpgy	.9299	.9297	.9298	1.4782	1.4789
No. 19	33.80	36.84	35.42	pgy	pgy	.9270	.9288	.9279	1.4765	1.4780
Seasonal average	32.97	35.81	......	......	......	.9274	.9293			
Highmore, S. Dak.:										
No. 3	33.99	34.56	34.27	vdgy	pgy	.9280	.9280	.9280	1.4780	1.4780
No. 12	33.42	36.00	34.71	pgy	vply	.9272	.9291	.9291	1.4780	1.4782
No. 13	33.20	34.44	33.82	pgy	pgy	.9277	.9287	.9282	1.4780	1.4780
No. 19	36.70	37.68	37.19	pgy	pgy	.9260	.9285	.9272	1.4773	1.4777
Seasonal average	34.32	35.67	......	......	......	.9272	.9286			
Archer, Wyo.:										
No. 3	31.44	37.80	34.62	dgy	gy	.9279	.9309	.9294	1.4773	1.4796
No. 12	32.24	38.76	35.50	dly	pgy	.9267	.9309	.9288	1.4777	1.4792
No. 13	33.44	38.20	35.82	gy	pgy	.9277	.9315	.9296	1.4782	1.4796
No. 19	36.30	40.40	38.35	gy	pgy	.9283	.9318	.9300	1.4778	1.4795
Seasonal average	33.35	38.79	......	......	......	.9276	.9312			
Burns, Oreg.:										
No. 3	35.38	34.84	35.11	gy	pgy	.9279	.9304	.9291	1.4790	1.4790
No. 12	32.40	33.40	32.90	pgy	pgy	.9280	.9294	.9289	1.4786	1.4787
No. 13	32.35	31.60	31.97	py	pgy	.9282	.9301	.9291	1.4780	1.4790
No. 19	37.10	33.20	35.15	py	pgy	.9275	.9299	.9287	1.4783	1.4786
Seasonal average	34.30	33.26	......	......	......	.9279	.9299			

The color of the oils from the various flax samples, while primarily golden yellow, differed considerably in the depth of the shade, varying from a deep golden yellow bordering on brown to a very pale lemon yellow or straw color. Whether there is any existing relationship between the color and the quality of the oils can not be definitely stated, unless it is found that the color properties can be correlated with some of the more important physical and chemical properties.

The specific gravity is a property which bears a certain relationship to the composition and hence is more closely related to the quality of the oils. Table II shows considerable variation among the Cereal Investigations numbers at any station during either season. When compared according to stations, the specific gravity shows a tendency to be high or low in several locations during both seasons. When grouped and averaged according to the stations at which the flax was grown and according to the Cereal Investigations numbers, some striking comparisons, which will be discussed in later pages, are made possible.

In Table II the index of refraction is given for the various oils, along with the specific gravity, as a physical property which is subject to similar variation, according to the composition of the oils. It will be noted that in practically all cases where the specific gravity is high the index of refraction is also high.

The acid, saponification, and iodin values[1] of the oils from the several stations were determined, together with the drying tests, and the results are arranged for comparison in Table III.

In considering the acid value of the linseed oils it will be seen that there is not only considerable variation in the oils from the various Cereal Investigations numbers during each of the seasons at each station, but the same number at other stations shows similar differences. The differences among the numbers at any station during either year may be due to difference in the type and character of the plants, but differences shown by the same number at different stations can probably be attributed to varying conditions of the harvested seed, the weather conditions during harvest, and the method of harvesting and storing.

No definite relationship seems to exist in the acid values of various samples at any one station during the two years. Comparison of the average acidity of samples grown at the various stations during the two years shows the variability of the acid values. In most cases the acidity of the oils from the 1914 samples was much higher than from the 1915 samples.

The saponification value, which represents the sum total of the free acids and glyceryl esters in the oils, will be seen to bear a close relationship to the acid values. The average of the saponification values of the oils from each station was higher during 1914 than during 1915, which is likewise true of the average acid value of the same oils.

In considering the iodin values of the several samples it will be seen that there is considerable individual variation among the several

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[1] Determinations of the chemical constants were made in accordance with the official and provisional method of analysis, Bureau of Chemistry Bulletin No. 107 (revised), 1910. The iodin values were obtained by means of the Hübl method, 4 hours being allowed in every case for the absorption of iodin. Complete iodin absorption doubtless did not take place in the above time. The results, however, serve well for the comparative purposes for which they are used.

varieties at any one station during either 1914 or 1915. Station averages are likewise variable during the two seasons. Some of the Cereal Investigations numbers are seen to possess fairly constant iodin values for the two years at particular stations, while others show some variation.

The iodin value, which depends upon the composition of the oil, is doubtless affected by conditions of season and growth.

TABLE III.—*Chemical properties and drying tests of various oils from the flax crops of 1914 and 1915.*

Station and C. I. No. of seed sample.	Acid value.			Saponification value.			Iodin value.			Time to dry (days).		
	1914	1915	Average.	1914	1915	Average.	1914	1915	Average.	1914	1915	Average.
Moccasin, Mont.:												
No. 3	0.78	0.60	0.69	191.0	188.7	189.8	156.6	156.2	156.4	18	14	16
No. 12	.79	.68	.73	189.3	192.8	191.0	156.0	153.5	154.7	18	10	14
No. 13	.83	.91	.87	192.4	189.7	191.0	159.3	154.0	156.6	18	10	14
No. 19	.79	.64	.71	191.4	186.6	189.0	159.2	155.0	157.1	14	15	14.5
Seasonal average	.797	.707	......	191.0	189.4	......	157.8	154.7	......	17	12.2	......
Dickinson, N. Dak.:												
No. 3	1.05	.81	.93	192.0	187.2	189.6	164.3	162.4	163.3	8	21	14.5
No. 12	.70	.85	.77	187.8	186.3	187.0	170.0	168.5	169.2	8	20	14
No. 13	.99	.86	.92	192.8	186.2	189.5	165.3	161.0	163.1	6	19	12.5
No. 19	1.36	.76	1.06	189.8	186.7	188.2	169.5	159.0	164.2	6	21	13.5
Seasonal average	1.025	.820	......	190.6	186.6	......	167.2	162.7	......	7	20.2	......
Mandan, N. Dak.:												
No. 3	1.11	.86	.98	192.5	199.8	196.1	164.3	160.7	162.5	10	20	15
No. 12	1.01	.95	.98	191.9	186.9	189.4	161.7	162.4	162.0	10	16	13
No. 13	1.04	.78	.91	190.2	187.0	188.6	162.4	163.3	162.8	10	18	14
No. 19	1.07	.55	.81	192.1	188.0	190.0	159.3	159.9	159.6	10	19	14.5
Seasonal average	1.057	.785	......	191.7	190.4	......	161.9	161.6	......	10	18.2	......
Newell, S. Dak.:												
No. 3	1.13	.67	.90	190.2	184.6	187.4	155.2	162.1	158.6	24	22	23
No. 12	1.11	.76	.93	191.4	185.9	188.6	154.0	159.5	156.7	26	22	24
No. 13	1.04	.74	.89	191.0	184.7	187.8	160.0	167.7	163.8	24	20	22
No. 19	1.00	.78	.89	188.7	187.7	188.2	161.8	158.0	159.9	20	20	20
Seasonal average	1.07	.737	......	190.3	185.7	......	157.7	161.8	......	23.6	21	......
Highmore, S. Dak.:												
No. 3	.93	.71	.82	195.6	187.9	191.7	162.0	160.3	161.1	23	18	20.5
No. 12	1.39	.74	1.06	193.6	187.9	190.7	157.7	161.4	159.5	21	12	16.5
No. 13	1.16	.55	.85	191.3	188.4	189.8	153.1	161.9	157.5	23	15	19
No. 19	1.66	.78	1.22	190.3	188.1	189.2	156.7	164.7	160.7	23	15	19
Seasonal average	1.285	.695	......	192.7	188.1	......	157.4	162.1	......	22.5	15	......
Archer, Wyo.:												
No. 3	.86	.90	.88	191.9	187.9	189.9	165.5	171.7	168.6	12	9	10.5
No. 12	.80	.93	.86	190.3	186.1	188.2	170.6	180.0	175.3	12	15	13.5
No. 13	.62	.90	.76	193.0	186.7	189.8	163.0	170.0	166.5	14	13	13.5
No. 19	.82	1.06	.94	182.3	186.9	184.6	167.5	165.5	166.5	9	12	10.5
Seasonal average	.775	.947	......	189.4	186.9	......	166.6	171.8	......	11.7	12.2	......
Burns, Oreg.:												
No. 3	.95	.44	.69	189.1	188.4	188.7	161.4	158.0	159.7	20	10	15
No. 12	1.03	.37	.70	190.7	185.0	187.8	167.8	158.4	163.1	18	10	14
No. 13	.90	.62	.76	192.4	187.3	189.8	160.1	160.3	160.2	18	8	13
No. 19	1.02	.60	.81	192.6	188.9	190.7	158.0	157.0	157.5	18	8	13
Seasonal average	.975	.507	......	191.2	187.4	......	161.8	158.4	......	18.5	9	......

In addition to the physical and chemical properties of the oils under discussion, the drying property, which is of importance, was deter-

mined in order to ascertain the relative rapidity with which the various oils dried to the customary film characteristic of drying oils.

The drying tests were conducted by spreading a thin film of oil over ground-glass plates 2 inches square and allowing the film to dry by exposure to the air, due precaution being taken to prevent the accumulation of dust on the surface. The experiments were conducted indoors at ordinary room temperature during the winter and early spring months.

Approximately the same weight (about 0.1820 gm.) of oil was used in every case, the oil spreading over an area of about 1½ square inches. The glass plates with the film of oil were weighed at definite intervals until no further increase in weight was observed, the time of complete drying being expressed in days. The average increase in the weight of all the oils varied from 12 to 14 per cent.

Comparison of the drying tests in Table III shows that certain Cereal Investigations numbers at different stations produce oils which dry more rapidly or more slowly than others.

Some stations show a close relationship among the Cereal Investigations numbers in the time of drying during the two seasons, while others show considerable variation in this respect. The effect of seasonal variation upon the composition of the oils at the stations is again evident.

A study of this nature admits of two general comparisons, namely, (1) a comparison of the several Cereal Investigations numbers and (2) a comparison of stations with respect to the oils produced during the two seasons.

In order that the data given in Tables II and III as related to the several Cereal Investigations numbers may be more readily compared, the yearly and general average yield, the specific gravity, the acid value, the iodin value, and the time of drying of the oils were computed and the results assembled in Table IV.

TABLE IV.—*Comparison of yield, specific gravity, acid value, iodin value, and time of drying of oils from the four flax varieties grown in 1914 and 1915.*

Seed sample.	Yield of oil (per cent).				Specific gravity.				Acid value.				Iodin value.				Time of drying (days).			
	Yearly average.		General average.	Rank.	Yearly average.		General average.	Rank.	Yearly average.		General average.	Rank.	Yearly average.		General average.	Rank	Yearly average.		General average.	Rank.
	1914	1915			1914	1915			1914	1915			1914	1915			1914	1915		
No. 3	34.59	35.65	35.11	2	0.9281	0.9297	0.9289	2	0.972	0.713	0.841	4	161.3	161.6	161.1	3	16.4	16.3	16.35	4
No. 12	32.41	35.29	33.84	3	.9281	.9294	.9287	3	.975	.754	.861	2	162.5	163.4	162.9	1	16.1	15.0	15.57	3
No. 13	32.67	33.92	33.22	4	.9284	.9300	.9292	1	.940	.765	.851	3	160.4	162.6	161.5	2	16.1	14.7	15.43	2
No. 19	35.98	36.79	36.42	1	.9276	.9295	.9285	4	1.10	.738	.920	1	161.7	159.8	160.8	4	14.3	15.7	15.00	1

The yield of oil of the several Cereal Investigations numbers grown at all the stations during each season is strikingly constant. The relative position of each number with respect to the average yield of oil

during either season is identical. No. 19 produced the highest average yield, with No. 3 ranking second, followed in order by Nos. 12 and 13 during both seasons.

The annual average specific gravity of each Cereal Investigations number was lower in 1914 than in 1915. The ranking of the numbers with respect to specific gravity each year is very similar. Nos. 13 and 3 possess the same relative high specific gravity each year and in general average are followed closely by Nos. 12 and 19.

The 1914 oils were uniformly much higher in acid value than the 1915 oils. In general average C. I. No. 19 was highest in acidity, followed by Nos. 12, 13, and 3. Much less difference is noted in the yearly average of the iodin values of the several oils. No. 12 possessed the highest average iodin value during both years. No. 3 also occupied the same relative position during the two seasons. Arranged in decreasing order of their general average iodin value, the numbers rank as follows: 12, 13, 3, 19.

In general average of drying it will be seen that C. I. No. 19 dried the most rapidly, followed by Nos. 13, 12, and 3. This order was closely maintained during each season.

Constant differences appear to exist in the four varieties in some of the physical and chemical properties. Thus, C. I. Nos. 19 and 3 produced a constantly high yield of oil, while Nos. 12 and 13 produced a constantly low yield.

The specific gravity of C. I. No. 13 oils was constantly high at most of the stations during the period under observation, while No. 19 oils were low in comparison in most cases.

In acid value, C. I. No. 19 exceeded the other oils in most of the determinations during the two seasons. On the other hand No. 3 was constantly low in acid value.

Considerable difference was noted in the iodin values of the several oils at the several stations during the two seasons. C. I. Nos. 12 and 13 as a rule gave higher iodin values than Nos. 3 and 19, the latter being fairly constantly lower in this property.

C. I. No. 19 excelled the other samples in the time of drying, followed closely by Nos. 13 and 12, with No. 3 showing the slowest drying property during each year at nearly all of the stations.

The drying of the oil does not seem to be solely dependent upon any one property of the oil. Rapidity of drying apparently depends upon a combination of properties. Thus, an oil combining high iodin value with high acid value dries comparatively rapidly. Likewise, oils with high iodin values and high specific gravity also dry rapidly. Finally, oils combining high iodin values with high acidity and high specific gravity invariably dry very rapidly.

In order to compare the various stations or geographical sources of the flax varieties with respect to yield and properties of the oil, the

yearly averages and general averages were computed from the data given in Tables II and III, and the results are presented in Table V.

TABLE V.—*Comparison of yield, specific gravity, acid value, iodin value, and time of drying of oils from flax grown at seven different stations in 1914 and 1915.*

[The stations where the seed samples were grown are designated by numbers as follows: No. 1=Moccasin, Mont.; No. 2=Dickinson, N. Dak.; No. 3=Mandan, N. Dak.; No. 4=Newell, S. Dak.; No. 5=Highmore, S. Dak.; No. 6=Archer, Wyo.; No. 7=Burns, Oreg.]

Station.	Yield of oil (per cent).				Specific gravity.				Acid value.				Iodin value.				Time of drying (days).			
	Yearly average		General average.	Rank.	Yearly average.		General average.	Rank.	Yearly average.		General average.	Rank.	Yearly average.		General average.	Rank.	Yearly average.		General average.	Rank.
	1914	1915			1914	1915			1914	1915			1914	1915			1914	1915		
No. 1.....	34.35	33.87	34.11	6	0.9274	0.9290	0.9282	6	0.797	0.707	0.752	6	157.8	154.7	156.2	7	17.0	12.2	14.6	5
No. 2.....	34.52	34.82	34.67	3	.9307	.9292	.9299	1	1.025	.820	.922	2	167.2	162.7	164.9	2	7	20.2	13.6	2
No. 3.....	33.74	34.93	34.33	5	.9279	.9298	.9288	4	1.057	.785	.921	3	161.9	161.6	161.7	3	10	18.2	14.1	4
No. 4.....	32.97	35.81	34.39	4	.9274	.9293	.9283	5	1.070	.737	.903	4	157.7	161.8	159.7	5	23.6	21.0	22.3	7
No. 5.....	34.32	35.67	35.00	2	.9272	.9286	.9279	7	1.285	.695	.990	1	157.4	162.1	159.7	6	22.5	15.0	18.75	6
No. 6.....	33.35	38.79	36.07	1	.9276	.9312	.9294	2	.775	.947	.861	5	166.6	171.8	169.2	1	11.7	12.2	11.95	1
No. 7.....	34.30	33.26	33.78	7	.9279	.9299	.9289	3	.975	.507	.741	7	161.8	158.4	160.1	4	18.5	9.0	13.75	3

The results given in Table V show that the yield of oil from the groups of samples at the stations mentioned are for the most part fairly constant during the two seasons. The yield during 1914 was uniformly lower than in 1915 with two exceptions. Burns, Oreg., and Moccasin, Mont., averaged slightly higher in 1914 than in 1915.

The amount of precipitation at each station during the growing months in 1914 and 1915 is perhaps the most influential factor in affecting the yield of oil, since the proper growth and maturity of the flax plants are dependent largely upon the amount of moisture available to the plants. By consulting Table I it will be observed that the precipitation during the growing months in 1914 was less at all stations except one (Dickinson, N. Dak.) than in 1915. It is singular to note that when the greatest differences occurred in the yield of oil at these stations there was also the greatest difference in precipitation. Thus, samples from Newell, S. Dak., and Archer Wyo., gave much higher yields of oil in 1915 than in 1914. The precipitation at these stations during the growing months was likewise much greater in 1915 than in 1914.

The yield of oil from the samples from Moccasin, Mont., in 1914 (34.35 per cent) is but slightly higher than in 1915 (33.87 per cent). The precipitation during the growing months of these two seasons also shows but slight variation. Samples from Burns, Oreg., show a higher yield of oil in 1914 (34.30 per cent) than in 1915 (33.26 per cent). The precipitation was likewise greater in 1914 (4.27 inches) than in 1915 (2.90 inches).

It may therefore be stated that the yield of oil at any definite geographical locality as indicated by the results obtained at the seven stations specified is dependent largely upon the precipitation and evaporation at each station.

Arranging the stations in decreasing order of their oil yields, it is found that the Archer, Wyo., samples show the highest average yield of oil for the two seasons, followed by Highmore, S. Dak., Dickinson, N. Dak., Newell, S. Dak., Mandan, N. Dak., Moccasin, Mont., and Burns, Oreg. This ranking, in contrast to the results for different years, does not seem to be correlated to any extent with differences in precipitation between stations. Annual precipitation and evaporation and the nature of the soil in affecting the retention of moisture assume more importance in this connection. It may be noted also that the station with the highest average yield of oil (Archer, Wyo.) is the southernmost one (latitude 41° 42′).

The specific gravities as given in Table V, representing the average of all the Cereal Investigations numbers at each particular station, denote in a general way the density of the oils produced at a certain geographical locality.

The 1915 oils were almost without exception higher in specific gravity than during the previous year. The Dickinson, N. Dak., oils of 1914 and 1915 averaged the highest in specific gravity, while Archer, Wyo., and Burns, Oreg., followed in close order. Mandan, N. Dak., Newell, S. Dak., Moccasin, Mont., and Highmore, S. Dak., averaged considerably lower, the oils from Highmore, S. Dak., being conspicuously low, occupying the seventh position with respect to rank during both seasons. The oils from Moccasin, Mont., also occupied identical positions with respect to average low specific gravity, being sixth in order during the two years.

Certain of the stations were noticeably constant in producing oils of either high or low specific gravity during the two seasons. The generally lower specific gravities in 1914 may, like the yields of oil, be attributed to climatic and soil conditions.

The 1914 oils were higher in average acid value than the 1915 oils, no apparent constancy existing at any of the stations for the two years. The acid value, which is a measure of free acidity, fluctuates considerably among the several stations during each year. When the condition of the seed during harvest and subsequent storage is favorable, the liberation of free fatty acids takes place with rapidity.

The stations listed in the order of the decreasing acidity of their oils are as follows: Highmore, S. Dak., Dickinson, N. Dak., Mandan, N. Dak., Newell, S. Dak., Archer, Wyo., Moccasin, Mont., and Burns, Oreg.

The average iodin value of the oils from the various stations shows a certain relationship from year to year. Thus the Mandan, N. Dak., samples possessed nearly identical average iodin values during 1914

and 1915. Close relationship also existed in the Moccasin, Mont., and Burns, Oreg., samples. The Archer, Wyo., samples possessed high iodin values, occupying almost the same relative positions during both 1914 and 1915, as did also Dickinson and Mandan, N. Dak., while Highmore and Newell, S. Dak., and Moccasin, Mont., averaged constantly low.

In the time required for drying, a close relationship exists among several of the stations from year to year. The Archer, Wyo., samples show a comparatively uniform and short time for drying during both seasons. The Newell, S. Dak., oils required a uniformly longer time for drying than those from any of the other States. In both of the stations there is a certain relationship between the drying property and the physical and chemical properties. Thus, the Archer, Wyo., samples dried the most rapidly of all. These oils also possessed the highest average iodin values, high specific gravities, and moderately high acid values. The Newell, S. Dak., samples, on the other hand, were the slowest in drying and likewise possessed comparatively low iodin value, specific gravity, and acidity. The Dickinson, N. Dak., samples, ranking next to those of Archer in rapidity of drying, combined high iodin and acid values with high specific gravity. The Highmore, S. Dak., samples, ranking next to those from Newell, S. Dak., in slow-drying properties, combined very low iodin values and specific gravities with high acidity. The Mandan, N. Dak., samples, ranking fourth in drying property, combined medium-low iodin and acid values with low specific gravity, while the Moccasin, Mont., samples, ranking fifth in drying property, also combined very low iodin and acid values with low specific gravity. The same relationship appears, therefore, to exist between the drying property and the physical and chemical properties of the oils, when compared from the station standpoint, as exists when comparing the varieties at the several stations.

RELATION OF THE OILS TO THE SOURCE OF SEED.

Discussing the relation of geographical source to yield of oil it may be stated that while some variation occurs from year to year at any one locality, due largely to climatic conditions, certain stations may be said to produce flax showing higher average yields of oil than others. The Archer, Wyo., Highmore, S. Dak., and Dickinson, N. Dak., samples produced relatively high average oil yields, followed by those from Newell, S. Dak., and Mandan, N. Dak., while the Moccasin, Mont., and Burns, Oreg., samples produced relatively low yields during the two years under observation.

It is very probable from the results shown that the yield of oil from the various flax varieties is dependent to a certain extent upon the geographical location with the varying conditions of soil and climate.

With regard to the physical properties of the oils it will be seen that in most cases the station averages differ considerably from year to year.

A relationship appears to exist between specific gravity and color, the oils with the highest specific gravity being invariably lighter in color.

No relationship appears to exist between the acid value of the oils and the station at which they are produced. This is to be expected when it is considered that the acidity of an oil is due perhaps more to conditions of harvesting, handling, and storage of the seed than to agricultural factors.

The iodin values as well as the drying tests of the oils, from the standpoint of the stations, bear about the same relationship as the specific gravities. Since the iodin value is due to certain constituents in the oil, this particular property is doubtless influenced very much by the growth of the plants, which in turn is affected by the location of stations and changed climatic conditions.

The yields of oil from the different flax varieties varied considerably. Some varieties maintained comparatively high average yields during the two seasons under observation. The variability of the oil yields may be attributed to varietal differences in the plants in conjunction with conditions of growth and season.

It appears that certain of the Cereal Investigations numbers, such as Nos. 19 and 3, grown at the several stations during two successive seasons yielded constantly high percentages of oil. The other varieties, Nos. 12 and 13, show constantly low yields of oil.

Distinct differences are also noted in the specific gravities of the oils from the several varieties under consideration. Nos. 13 and 3 averaged higher than Nos. 12 and 19.

A marked fluctuation in acidity is noticed among the various Cereal Investigations numbers, no apparent relationship existing between them. The iodin values, on the other hand, bear a definite relationship to the Cereal Investigations numbers. Nos. 12 and 13 maintained high average iodin values, while Nos. 3 and 19 averaged somewhat lower from year to year. In the drying tests the varieties which show a tendency to dry rapidly or slowly are dependent to a large extent upon a combination of high iodin value with high specific gravity or high acid value.

CONCLUSIONS.

In conclusion, it may be stated that the results of the investigation show that varieties of flax possessing agronomic differences also differ in both the physical and chemical properties of the oils. Varieties possessing certain properties maintain these properties to a marked degree from season to season. From these results it may

be assumed that the climatic and soil conditions existing at the respective localities acted in conjunction in a similar manner from year to year in affecting the growth and development of the plant.

The yields of oil were found to vary with the variety of flax as well as with the locality in which it was grown. Thus, certain Cereal Investigations numbers gave constantly high or low yields of oils during the two years, and certain stations yielded flax samples with constantly high or low content of oil.

The physical properties, specific gravity, index of refraction, and color are apparently quite variable in many instances and are not so easily correlated with variety or locality.

A direct relationship appears to exist between the drying property of the oils and the specific gravity, acid value, and iodin value. Oils combining high acidity with high specific gravity and possessing a relatively high iodin value invariably dried to a firm film most rapidly. The relationship between the drying property and the color of the oils was also very marked. The lightest colored oils invariably possessed the most rapid drying properties.

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